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for Hypernuclear Studies**

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THE (K^-, η) REACTION FOR HYPERNUCLEAR STUDIES

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ABSTRACT

We study the feasibility of using the (K^-,η) reaction as a new tool for producing Λ-hypernuclei. We compare the characteristics of the (K^-,η) reaction with those of the (K^-,π) and (π^+, K^+) reactions and calculate the production cross sections for the $^{12}C(K^-, \eta)^{12}_\Lambda B$ reaction. Preliminary results of a test run at BNL to measure the (π^-, η) and the (K^-, η) reactions are presented.

1. Introduction

For about 30 years after the first discovery of Λ hypernuclei, the (K^-, π^-) reaction has been used almost exclusively for studying them. It was not until the mid 1980's that the feasibility of the (π^+,K^+) associated production reaction was established[1]. The (π^+,K^+) reaction was shown to complement the (K^-, π^-) reaction very well in the study of Λ-hypernuclear spectroscopy[2].

In addition to the (K^-, π^-) and the (π^+, K^+) reactions, there are other new experimental tools proposed for Λ-hypernuclear productions. For example, there are proposals to measure the $(e, e'\, K^+)$ reaction at the Jefferson Lab[3], and a proposal[4] at COSY to study the $(p, p'\, K^+)$ reaction. A new experiment[5] at BNL will measure the (K^-, π^0) reaction. In contrast to the (K^-, π^-) and the (π^+,K^+) reactions, which

turn a neutron into a Λ, these new reactions change a proton into a Λ. The unique features of the (K^-, π^0) reaction have been discussed in Refs. 5-7.

The BNL (K^-, π^0) experiment will utilize a stopped K^- beam which offers the interesting opportunity to achieve high resolutions. Futhermore, the $(K^-_{stopped}, \pi^0)$ experiment could detect the π° mesonic decay modes of light Λ-hypernuclei, where very little experimental data exist. Ideally, one would also like to measure the (K^-, π^0) reaction using an in-flight K^- beam. The selectivity for the in-flight (K^-, π^0) reaction is expected to be different from that of the $(K^-_{stopped}, \pi^0)$ reaction. Moreover, the in-flight data are not subject to a potentially large π° background originating from K^- absorption. In practice, however, it is difficult to measure the in-flight (K^-, π^0) reaction with good energy resolution and solid angle acceptance. An alternative method would be the (K^-, η) reaction, which has the advantage that η could be detected with relatively good energy resolution and large acceptance. Both η and π^0 mesons are detected through their 2γ decay mode, and a neutral meson spectrometer is capable of detecting them. In this note we discuss the characteristics of the (K^-, η) reaction and present preliminary results obtained in a recent E907 test run using the LAMPF Neutral Meson Spectrometer (NMS).

2. Characteristics of the (K^-, η) reaction

In Figure 1, we show the kinematics of the (K^-, η) and the (K^-, π^0) reactions on a ^{12}C target. The threshold for the ^{12}C(K^-, η) reaction is at P(K^-) = 560 MeV/c, and the η mesons are produced with relatively low energies. Being massive and slow-moving, the η meson produces a distinct signal in the $\eta \rightarrow \gamma + \gamma$ decay, namely a pair of energetic gamma rays with large opening angle between them. The large opening angle implies that the spectrometer can be placed close to the target with good solid-angle coverage. The (K^-, η) reaction has the advantage that it is free from the $K^- \rightarrow \pi^0 \pi^-$ decay-in-flight background present in the (K^-, π^0) reaction.

In Figure 2 the momentum transfer for the ^{12}C(K^-, η) reaction is shown as a function of the beam momentum. For comparison, the momentum transfers for the (K^-, π^0) and (π^+, K^+) reactions are also shown. The momentum transfer for the (K^-, η) reaction at 750 MeV/c is comparable to that of the (K^-, π^0) reaction at rest, and the (K^-, η) reaction has similar but somewhat smaller momentum transfer compared with the (π^+, K^+) reaction.

The existing data on the $K^- + p \rightarrow \eta + n$ reaction[8] show that the total cross section peaks at beam momentum around 750 MeV/c, not far above the threshold at 720 MeV/c. The $\Lambda(1670)$ S01 resonance is responsible for the enhancement of the cross sections near threshold energy. The optimal beam momentum for measuring the (K^-, η) reaction is therefore around 750 MeV/c.
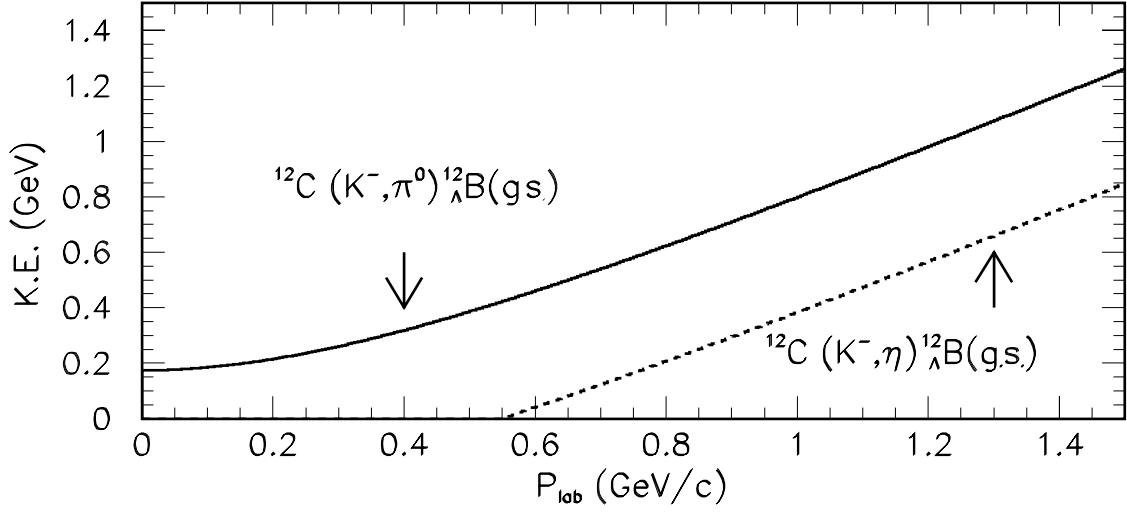
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Figure 1: Kinetic energies of π^0 and η at $\theta_{lab} = 0°$ for the (K^-, π^0) and (K^-, η) reactions on ^{12}C.
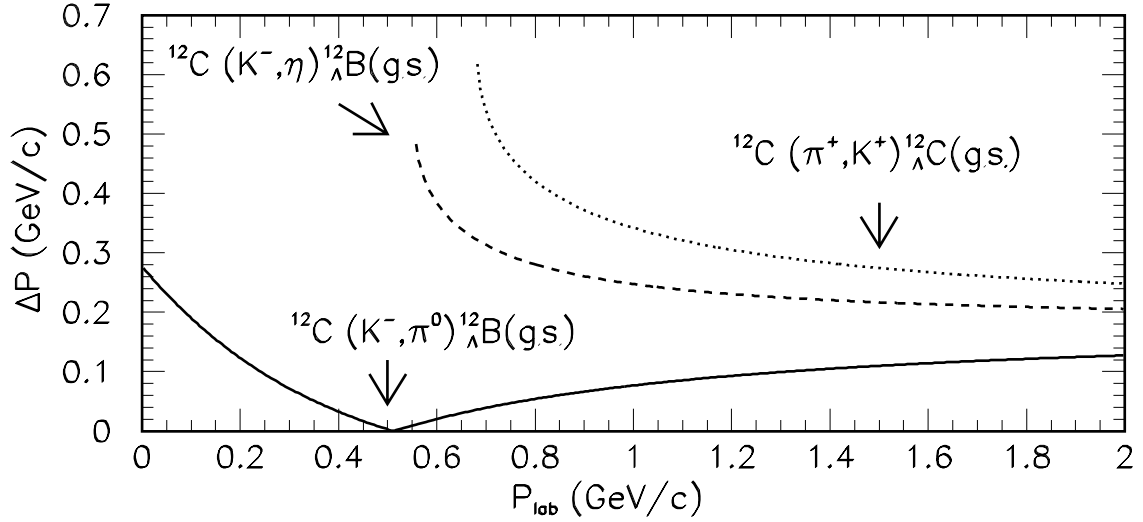

Figure 2: Comparison of the momentum transfer at $\theta_{lab} = 0°$ for three reactions.
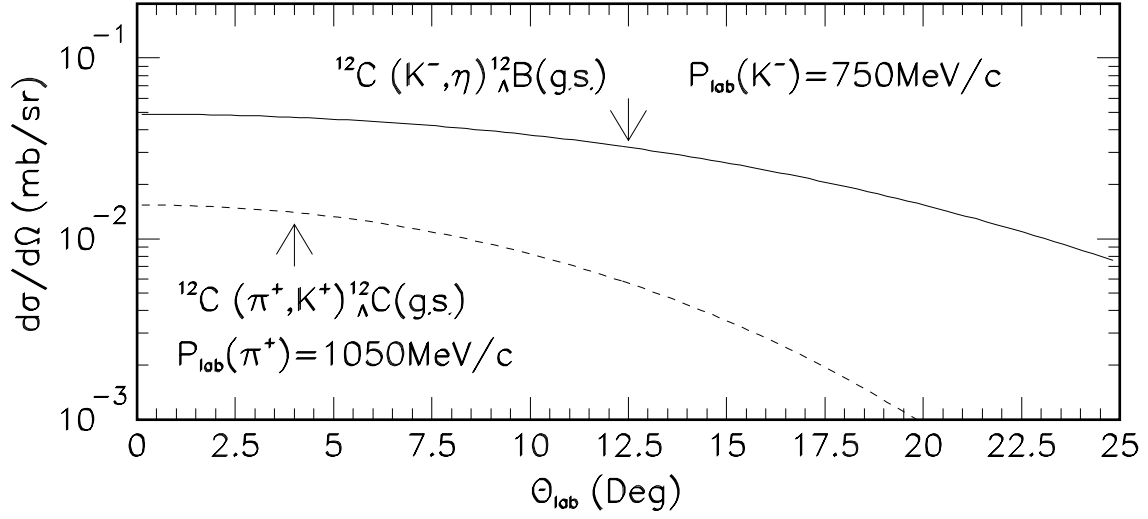
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Figure 3: Predictions of DWBA calculations for the differential cross sections of the (K^-, η) and (π^+, K^+) reactions on ^{12}C.

To estimate the cross sections expected for producing Λ-hypernuclear states, we have performed DWBA calculations using the code CHUCK[9]. The calculation is analogous to those for the (K^-, π^-) reaction[10] with the cross section for the subprocess $K^- + n \to \pi^- + \Lambda$ replaced by that of $K^- + p \to \eta + \Lambda$. The optical potential for η - nucleus interaction was assumed to be the same as that of the π^--nucleus interaction. Figure 3 shows the differential cross sections for the $^{12}C(K^-, \eta)^{12}_\Lambda B(g.s.)$ transition at $P(K^-) = 750$ MeV/c. For comparison, the calculation for the $^{12}C(\pi^+, K^+)^{12}_\Lambda$ C(g.s.) transition at $P(\pi^+) = 1050$ MeV/c is also shown. The calculated (π^+, K^+) cross sections are in good agreement with the data[1,2]. Figure 3 shows that the cross sections for the (K^-, η) reaction are roughly three times greater than that of the (π^+, K^+) reaction. The (K^-, η) reaction also has a flatter angular distribution.

3. Results from a test run

During the test run in 1996 for the AGS experiment E907, we had an opportunity to study the (K^-, η) reaction. Some information on the details of the E907 experiment can be found in Ref. 11. For the (K^-, η) test run, we used a 750 MeV/c beam incident on 12 layers of 1/4 inch thick CH scintillator targets. The two arms of the NMS spectrometer were positioned at ~ 60 cm from the target with an opening angle of $\sim 90°$. One arm of the NMS is above the beam while the other one below, and the bisector of the two arms is along the beam direction.

The experiment triggered on events which deposited at least 75 MeV in the CsI
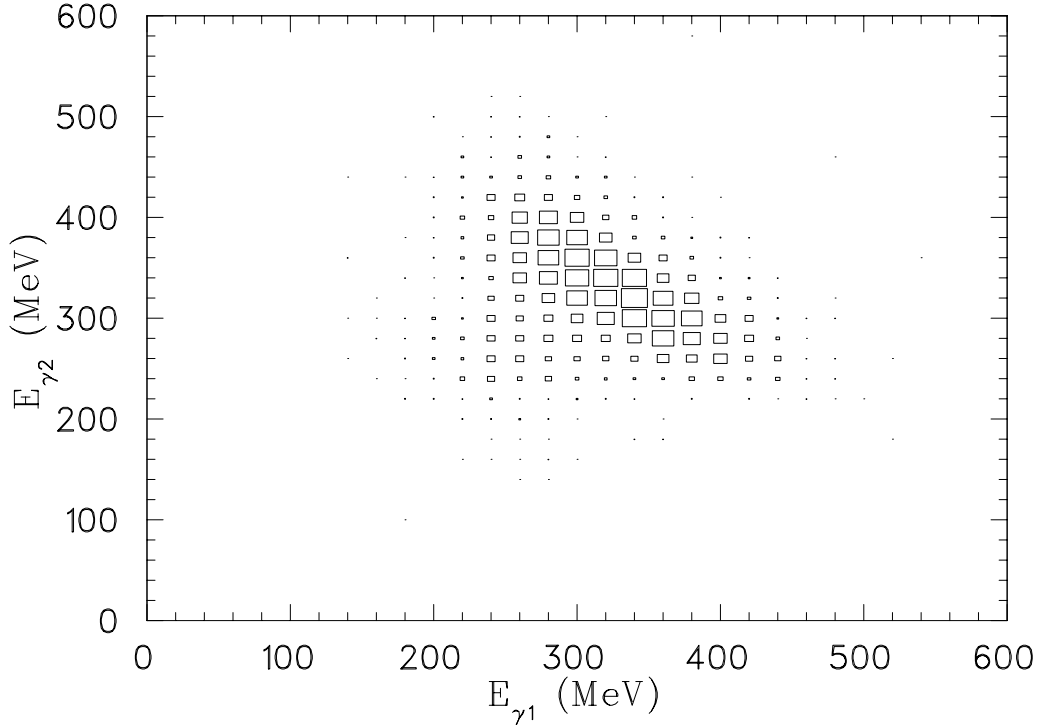
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Figure 4: $E_{\gamma 1}$ versus $E_{\gamma 2}$ for events detected with NMS using a 750 MeV/c π^- beam.

calorimeters in each NMS arm. Since the beam consists of both K$^-$'s and π^-'s, we could measure the (π^-, η) as well as the (K^-, η) reactions. The time-of-flight information provided a good identification for the beam particle type. Figure 4 shows a 2D plot of $E_{\gamma 1}$ versus $E_{\gamma 2}$, where $E_{\gamma n}$ is the total shower energy deposited in arm n, for events triggered by incident pions. The η's are clearly visible in Figure 4 as those events which deposited on the average 340 MeV in each NMS arm. From $E_{\gamma 1}, E_{\gamma 2}$, and the opening angle between the two γ's, one can calculate the invariant mass. Figure 5.a shows the invariant mass distribution of the 2γ's produced with $\sim$ 4 hours of π^- beam.

Figure 5.b shows the invariant mass distribution of the 2γ's produced with a K$^-$ beam. The η peak is clearly seen. The observed invariant mass resolution for the η is in good agreement with Monte-Carlo simulations. Most of the (K^-, η) events are expected to come from the K$^-$ + p $\rightarrow \eta + \Lambda$ reaction, while some of them should originate from the ^{12}C$(K^-, \eta)^{12}_\Lambda$B reaction. Figure 5.b represents data collected in $\sim$12 hours of good beam. This test run indicates that it is quite feasible to detect the (K^-, η) reaction at an existing kaon facility. It would be very desirable to construct a high-resolution large-acceptance neutral meson spectrometer at JHP for studying the (K^-, π^0) and the (K^-, η) reactions in the future.

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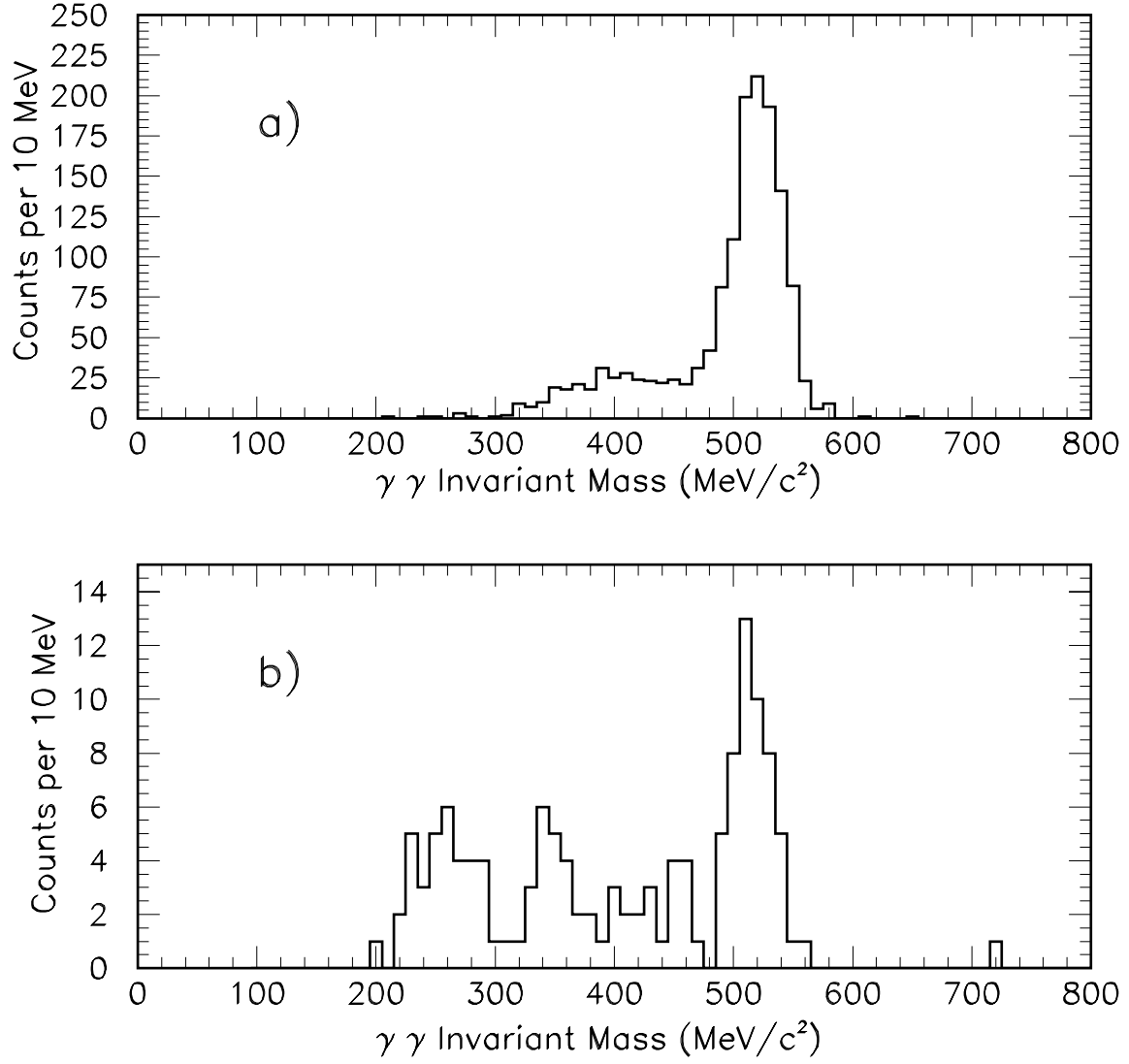
Figure 5: $\gamma\gamma$ invariant mass distribution for events detected with NMS using a) a 750 MeV/c π^- beam, and b) a 750 MeV/c K^- beam.

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